UNIVERSITY OF PENNSYLVANIA

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# THE RANGE OF VISUAL ATTENTION, COGNITION AND APPREHENSION FOR COLORED STIMULI

JOHN R. HART, JR.

A THESIS

IN PSYCHOLOGY

PRESENTED TO THE FACULTY OF THE GRADUATE SCHOOL IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

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# THE RANGE OF VISUAL ATTENTION, COGNITION, AND APPREHENSION FOR COLORED STIMULI

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Recent experiments on the 'Range of Attention' problem have made it evident that the usual experimental procedure and instructions give results for a mental process much more complicated than could possibly be included within the term Attention.[1] In order to further study this difficulty, Oberly,[2] on the basis of preliminary introspective reports, calculated the statistical limens for three typical processes which he called attention, cognition, and apprehension.

Oberly employed black stimuli on a white background exposed tachistoscopically. He found that each of his three systematic categories gave characteristically different thresholds: those for attention being smallest, cognition next, and apprehension largest. In the present study, Oberly's systematic analysis of the problem has been accepted and an attempt is made to determine the effect of color upon the statistical limens for each of Oberly's categories.

## EXPERIMENTAL PROCEDURE

The introspective reports of the *O*s indicate that there are possible, and of very frequent occurrence, 3 conscious patterns which form the basis of the verbal report of the stimuli perceived. These 3 patterns were described as follows: (1) *Immediate.* All the dots were perceived in a single flash of consciousness, with an equal and high degree of clearness. (2) *Grouping.* All the dots were seen in a single flash of consciousness, but owing to different degrees of clearness, there was an attentional grouping of the stimulus dots. Both of the 2 conscious patterns characterized above, however, gave rise at once to the verbal report without any mediating conscious processes. (3) *Counting.* This process was different from either of the other two, inasmuch as the report was always made on the basis of some subsequent re-imaging of the stimulus material. The mediating process varied from *O* to *O* and for the same *O* from time to time. The processes consisted frequently in visual images, the dots of which were then counted verbally; or of a verbal counting with ocular-motor fixation of the position of the dots or other similar sorts of processes. Also, all of the *O*s reported wide differences in the degree of subjective assurance with which the judgments were reported.

*Apparatus.* Three sets of gray cards 87 mm. square were prepared. From 2 to 12 round dots of each color (6.5 mm. in diam.): blue, green, yel-

*Accepted for publication May 9, 1927.

[1]Cf. S. W. Fernberger, A preliminary study of the range of visual apprehension, this JOURNAL, 32, 1921, 121-133.
K. M. Dallenbach, Attributive *vs.* cognitive clearness, *J. Exper. Psychol.*, 3, 1920, 183-230.

[2]H. S. Oberly, The range for visual attention, cognition, and apprehension, this JOURNAL, 35, 1924, 332-352.

low or red of the Hering papers in each set, were pasted in haphazard arrangements on the gray backgrounds. Each set was homogeneous. All of these were exposed by means of a Whipple tachistoscope with an exposure of 40 sigma. There were 44 cards in each set, making 132 in all. The order of the stimulus cards was different in each of the three sets and was arranged in haphazard fashion. After the exposure of all the cards, they were turned 90° so that the right edge of each card was now the bottom of the card for the next group of exposures. This method of rotating the cards was continued throughout the experiment. Thus any stimulus card was seen in the same (identical) position only after each 528th exposure. In this manner and also by starting at the different ends of each series the probability of the *O*'s memorizing the order of the series or of his recognizing any particular card was very much reduced.

The photographic dark room of the laboratory was used in order to keep the illumination on the stimulus card and the general illumination constant, the only source of light being that of the exposure lamp. The *O* was seated 1.9 m. from the pre-fixation screen. Each *O* gave 2,200 judgments for each fractionated series, making 4,400 total, or 400 judgments for each number of dots, 100 judgments for each color of each number of dots.

*Instructions.* The directions which were read to the *O* at the beginning of each experimental sitting were as follows: "You will be shown successively, for a very brief exposure, cards which contain a varying number of dots. Look at these and report as follows.

"(1) The number of dots you have seen.

"(2) The degree of assurance or certainty of your judgment, using the following scale for your report: 5—if it is a 100 to 1 bet, 4—if it is a 5 to 1 bet, 3—if it is a 1 to 1 bet, 2—if it is a 1 to 5 bet, 1—guess or do not know.

"(3) An introspective characterization as follows: (1) *Immediate*, which means that the dots were perceived in a single flash of attention and were ungrouped. (2) *Grouping*, which means that the dots were seen in a single flash of attention but were grouped. (3) *Counting*, which means that the dots were re-imaged in some fashion, subsequent to the exposure, other than for verification, and were subsequently counted."

Each *O* was given some practice in following these directions before the record was taken of his judgments.

It is obvious that the introspective characterizations do not correspond to the systematic categories that have appeared in the psychological literature.[3] It was necessary therefore to transform the results obtained into some form of systematic categories for the purpose of study and of calculation. From a study of the literature it seems that the introspective characterization which has been described above and which appears in the instructions as 'immediate' corresponds to one-level attention. These results have therefore been calculated under this heading.

The term 'cognition' as it appears in the psychological literature seems to be a process which is immediate but which does not imply only a single level of clearness. The principal aspect which characterizes cognition is its immediacy. It will be observed that the introspective categories of *Immediate* and *Grouping* are both characterized by their immediacy, although the second is further characterized by different degrees of clearness which lead to an attentional grouping. The results of these two introspective categories have therefore been combined under the title of cognition.

The term 'apprehension' as it appears in the psychological literature signifies the obtaining of a knowledge of the stimulus without restriction of the processes underlying such knowledge. All three of the introspective categories have therefore been combined for purposes of calculation for

[3]This argument follows Oberly's analysis noted above.

this systematic concept. In other words, the results of both *Immediate* and *Grouping*, as the two ways of getting knowledge without subsequent process, have been combined for *Counting*, which involves such a mediating process.

The results for Attention consist solely of those which were characterized as immediate and ungrouped by the *O*s. The results for Cognition are those which the *O*s characterized as immediate plus those characterized as grouped; and finally, the results for Apprehension are a combination of the results which were characterized by the *O*s under all three introspective headings.

It was arbitrarily determined to use for purposes of calculation only those reports which were correct and which had an assurance of 5, 4, or 3. This means that the *O* was sure enough of his report to put even money on it, and this procedure eliminates the doubtful judgments. Therefore, judgments with the assurance of 2 or 1 were eliminated from the calculations, but not from the reports. Two *O*s (YN and MM) worked in entire ignorance of this elimination.

The results for each of the 3 systematic categories were fractionated into 2 groups of 50 judgments for each value of the stimulus in the order taken. The calculations were made in accordance with the phi-gamma hypothesis, and these calculations were simplified by the use of Urban's Tables. Such a calculation yields a statistical threshold as well as a statistical index of precision of the results, for each of our 3 systematic categories, for each of the 4 colors, and for each of the 3 degrees of assurance that were retained.

*Observers.* Four *O*s were chosen from the staff of the department. They were H. Sherman Oberly (SO), Stanley F. Cooper, (SC), Yale Nathanson (YN), and Miles Murphy (MM), Instructors of Psychology. Two of the *O*s, SO and SC, were well acquainted with the materials and the methods of exposure. YN and MM were trained in giving introspective reports in psychological experiments, but were not trained in this particular experiment.

## Results

The tables of the observed relative frequencies of correct judgments for each of the 3 systematic categories and for each of the 3 degrees of subjective assurance—16 tables in all—have been omitted in an effort to conserve space. In every case, the curves approached the ogive type, starting with high relative frequencies for the smaller values of stimulus and descending to small observed relative frequencies for the higher values of stimulus. Very few inversions are noted in the curves and those that do occur are slight. These observed relative frequencies were therefore treated statistically by the phi-gamma hypothesis assisted by the use of Urban's Tables.

Such a treatment yields two sets of values of statistical significance. (1) The statistical threshold or limen (S) which gives that value of stimulus which is correctly reported with a probability of 0.5 or which is as likely to be correctly reported as not. (2) An index of precision (h) which gives an index of the degree of scatter or of the steepness of the curve. These statistical values (S and h) will be found in Tables I to IV.

Each table contains the complete results for a single *O*. Each table is divided into three parts: the upper third containing the results for subjective assurance 5 alone; the middle third for assurance 5 and 4; and the lower third for assurances 5, 4, 3. The results for each color are found in two columns, the first giving the values of the limens (S) and the second the values of the indices of precision (h) respectively. In each third, the first 2 rows contain the results for Attention, the next 2 rows those for Cognition, and the last 2 rows those for Apprehension. The first and second series into which the results have been fractionated are indicated in each case.

TABLE I
Observer SO

| Assurance | Category | Series | Blue | | Green | | Yellow | | Red | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | S | h | S | h | S | h | S | h |
| 5 | Attention | I | 4.06 | 1.07 | 3.90 | 0.75 | 4.43 | 1.15 | 4.56 | 1.15 |
| | | II | 3.64 | 0.23 | 3.27 | 0.21 | 4.12 | 1.24 | 6.02 | 0.63 |
| | Cognition | I | 6.42 | 0.53 | 6.31 | 0.39 | 6.40 | 0.60 | 6.75 | 0.49 |
| | | II | 7.39 | 0.44 | 7.49 | 0.45 | 7.69 | 0.59 | 8.12 | 0.46 |
| | Apprehension | I | 7.18 | 0.56 | 6.85 | 0.41 | 6.73 | 0.54 | 7.34 | 0.46 |
| | | II | 8.28 | 0.45 | 7.99 | 0.48 | 8.32 | 0.54 | 8.73 | 0.39 |
| 5 + 4 | Attention | I | 4.06 | 1.07 | 3.90 | 0.75 | 4.43 | 1.15 | 4.56 | 1.15 |
| | | II | 3.64 | 0.23 | 3.27 | 0.21 | 4.12 | 1.24 | 6.02 | 0.63 |
| | Cognition | I | 6.59 | 0.49 | 6.49 | 0.34 | 6.54 | 0.63 | 6.97 | 0.48 |
| | | II | 7.46 | 0.44 | 7.49 | 0.45 | 7.77 | 0.58 | 8.21 | 0.46 |
| | Apprehension | I | 7.56 | 0.56 | 7.07 | 0.38 | 6.96 | 0.57 | 7.89 | 0.52 |
| | | II | 8.38 | 0.36 | 8.25 | 0.45 | 8.49 | 0.53 | 8.97 | 0.42 |
| 5 + 4 + 3 | Attention | I | 4.06 | 1.07 | 4.00 | 0.91 | 4.43 | 1.15 | 4.56 | 1.15 |
| | | II | 3.64 | 0.23 | 3.27 | 0.21 | 4.12 | 1.24 | 6.02 | 0.63 |
| | Cognition | I | 6.84 | 0.49 | 6.69 | 0.36 | 6.90 | 0.53 | 7.33 | 0.42 |
| | | II | 7.76 | 0.38 | 7.98 | 0.32 | 7.91 | 0.56 | 8.61 | 0.39 |
| | Apprehension | I | 8.62 | 0.44 | 7.98 | 0.35 | 8.20 | 0.44 | 8.85 | 0.40 |
| | | II | 9.02 | 0.33 | 9.01 | 0.45 | 8.93 | 0.44 | 10.31 | 0.38 |

The results with regard to the thresholds (S) come out very similar to those of Oberly. The thresholds for Attention are smallest, those for Cognition next, and those for Apprehension largest. This is true for all 4 *O*s and for all degrees of assurance. As one compares the results for the different *O*s there is surprisingly little variation; the average threshold for Attention being approximately 4, that for Cognition, 7 to 8; that for Apprehension of the magnitude, 9 to 10. As one compares the results of the first series with those of the second fractionated series, a certain amount of progressive practice is evident. The degree of increase in the threshold as the result of practice,

however, is much greater for apprehension than for cognition and attention. This would indicate better methods of re-imaging the stimuli, and an improvement in the mediating process.

The examination of the size of the thresholds (S) for SO, Table I, indicates that for all 6 series, Attention, Cognition, and Apprehension, the limen for Red is invariably higher than that for any of the other colors. The position of the other colors is not quite so evident, although Green has certainly the lowest limen (second—1; third—5; fourth—12 of the total eighteen cases). Yellow and Blue are intermediate and not very different. Yellow, however, was in second place more often than Blue (Yellow—11 seconds; Blue—6 seconds). The average position of the colors seems clearly to be Red with the highest limen, Yellow, Blue, and Green with the lowest limen.

TABLE II
Observer SC

| Assurance | Category | Series | Blue | | Green | | Yellow | | Red | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | S | h | S | h | S | h | S | h |
| 5 | Attention | I | 5.18 | 1.20 | 3.94 | 0.74 | 4.62 | 0.57 | 5.28 | 0.93 |
| | | II | 5.73 | 1.15 | 5.12 | 1.72 | 5.00 | 1.68 | 5.42 | 2.84 |
| | Cognition | I | 7.36 | 0.54 | 5.24 | 0.34 | 6.44 | 0.30 | 7.16 | 0.51 |
| | | II | 7.85 | 0.70 | 7.21 | 0.56 | 6.92 | 0.52 | 7.89 | 0.55 |
| | Apprehension | I | 7.40 | 0.54 | 5.33 | 0.32 | 6.49 | 0.30 | 7.33 | 0.50 |
| | | II | 7.87 | 0.69 | 7.04 | 0.54 | 6.96 | 0.52 | 7.85 | 0.54 |
| 5 + 4 | Attention | I | 5.18 | 1.20 | 3.97 | 0.74 | 4.72 | 0.49 | 5.28 | 0.93 |
| | | II | 5.73 | 1.15 | 5.12 | 1.72 | 5.00 | 1.68 | 5.42 | 2.83 |
| | Cognition | I | 8.10 | 0.54 | 5.90 | 0.32 | 7.43 | 0.41 | 7.85 | 0.43 |
| | | II | 8.28 | 0.71 | 7.80 | 0.53 | 7.58 | 0.58 | 8.38 | 0.53 |
| | Apprehension | I | 8.43 | 0.53 | 6.40 | 0.27 | 8.01 | 0.27 | 8.35 | 0.40 |
| | | II | 8.56 | 0.60 | 8.18 | 0.51 | 7.87 | 0.51 | 8.61 | 0.48 |
| 5 + 4 + 3 | Attention | I | 5.18 | 1.20 | 4.00 | 0.73 | 4.72 | 0.49 | 5.28 | 0.93 |
| | | II | 5.73 | 1.15 | 5.12 | 1.72 | 5.00 | 0.17 | 5.42 | 2.83 |
| | Cognition | I | 8.02 | 0.54 | 7.89 | 0.42 | 7.77 | 0.48 | 8.05 | 0.51 |
| | | II | 8.52 | 0.66 | 8.05 | 0.48 | 7.80 | 0.65 | 8.80 | 0.61 |
| | Apprehension | I | 9.82 | 0.34 | 8.25 | 0.27 | 8.84 | 0.38 | 9.89 | 0.35 |
| | | II | 10.89 | 0.25 | 9.92 | 0.28 | 9.52 | 0.23 | 10.26 | 0.33 |

The results of SC, Table II, would indicate that Red and Blue are tied for first place with regard to highest limen, each being in the first position 9 times and in the second position 9 times. Average differences between Red and Blue, however, are not very great. These results hold for all 3 categories of Attention, Cognition, and Apprehension, and for all 3 degrees of subjective assurance. Similarly, Green and Yellow fall into another and significantly different group for third and last place. Green has the third highest limen 10 times and the fourth highest limen 8 times; Yellow has

the third highest limen 8 times and the lowest limen 10 times. Again the sizes of these limens are not significantly different from those of the limens for Red and Blue.

In Table III, the results for YN would indicate that Red has clearly the highest limen for all the cases of judgment and for all 3 degrees of subjective assurance—the limen for Red being highest in 14 of the 18 cases and in second place 4 times. A somewhat anomalous condition was found with regard to the relative position of the limens for Yellow and Blue. If Attention and Cognition are alone considered, Yellow is clearly in second place, the score being 2 firsts, 8 seconds, and 2 thirds for Yellow, and 2 seconds with 10 thirds for Blue. The values, however, are not significantly

TABLE III
Observer YN

| Assurance | Category | Series | Blue | | Green | | Yellow | | Red | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | S | h | S | h | S | h | S | h |
| 5 | Attention | I | 4.32 | 0.42 | 4.22 | 0.58 | 4.45 | 0.43 | 4.46 | 0.40 |
| | | II | 5.24 | 0.68 | 4.86 | 0.52 | 5.30 | 0.54 | 5.45 | 0.67 |
| | Cognition | I | 6.14 | 0.36 | 6.11 | 0.33 | 6.82 | 0.29 | 6.41 | 0.33 |
| | | II | 7.04 | 0.30 | 6.80 | 0.23 | 7.11 | 0.32 | 7.54 | 0.26 |
| | Apprehension | I | 6.57 | 0.42 | 6.32 | 0.34 | 7.15 | 0.39 | 7.11 | 0.25 |
| | | II | 8.16 | 0.48 | 8.14 | 0.44 | 7.99 | 0.44 | 8.81 | 0.43 |
| 5 + 4 | Attention | I | 4.26 | 0.36 | 4.21 | 0.44 | 4.47 | 0.43 | 4.50 | 0.41 |
| | | II | 5.24 | 0.68 | 4.86 | 0.52 | 5.30 | 0.54 | 5.45 | 0.67 |
| | Cognition | I | 6.95 | 0.28 | 6.62 | 0.28 | 7.15 | 0.31 | 7.02 | 0.31 |
| | | II | 7.50 | 0.25 | 7.45 | 0.19 | 7.49 | 0.27 | 8.17 | 0.21 |
| | Apprehension | I | 7.59 | 0.35 | 6.95 | 0.29 | 8.53 | 0.38 | 7.98 | 0.43 |
| | | II | 8.58 | 0.39 | 8.71 | 0.41 | 8.45 | 0.41 | 9.37 | 0.41 |
| 5+4+3 | Attention | I | 4.33 | 0.36 | 4.26 | 0.43 | 4.47 | 0.43 | 4.51 | 0.40 |
| | | II | 5.24 | 0.68 | 4.86 | 0.52 | 5.30 | 0.54 | 5.35 | 0.67 |
| | Cognition | I | 7.38 | 0.25 | 7.15 | 0.25 | 7.40 | 0.30 | 7.51 | 0.25 |
| | | II | 8.14 | 0.17 | 7.75 | 0.16 | 7.88 | 0.21 | 9.99 | 0.19 |
| | Apprehension | I | 8.26 | 0.30 | 8.45 | 0.35 | 7.95 | 0.34 | 8.48 | 0.30 |
| | | II | 9.28 | 0.35 | 8.91 | 0.36 | 8.82 | 0.36 | 9.87 | 0.36 |

different. In the case of Apprehension, Blue seems clearly in second place with 2 seconds and 4 thirds for Blue as against 2 firsts and 4 fourths for Yellow, but again, the differences are not significantly different. Green very clearly gives the lowest limen, being lowest 14 times, second twice and third twice.

In the case of MM, Table IV, there is slightly more scatter than will be observed in the results of the other *O*s. However, Red gives, in general, clearly the highest limen, being in first place 11 times, in second place 7 times, and in third place only once. Similarly, Green gives in general, the lowest limen, being lowest 10 times, in first place 4 times, and in third place 4 times. These thresholds for Red and Green on the whole would seem to be significantly different from one another. Blue and Yellow are

clearly intermediate. It is with difficulty that one would determine which had, in general, the highest values. The score stands, Blue first, 3 times; second, 5 times; third, 4 times; and lowest, 6 times. Yellow gives the highest limen once, the second highest, 6 times, third highest, 9 times, and the smallest limen, twice.

TABLE IV

Observer MM

| Assurance | Category | Series | Blue | | Green | | Yellow | | Red | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | S | h | S | h | S | h | S | h |
| 5 | Attention | I | 3.94 | 0.48 | 4.27 | 0.71 | 4.14 | 1.14 | 4.26 | 0.97 |
| | | II | 4.61 | 1.80 | 4.59 | 1.86 | 4.71 | 2.07 | 4.90 | 1.28 |
| | Cognition | I | 6.91 | 0.80 | 6.58 | 0.73 | 6.65 | 0.71 | 6.82 | 0.74 |
| | | II | 7.54 | 0.81 | 7.83 | 0.68 | 8.02 | 0.66 | 8.93 | 0.36 |
| | Apprehension | I | 6.99 | 0.79 | 6.63 | 0.76 | 6.85 | 0.67 | 6.86 | 0.77 |
| | | II | 8.26 | 0.75 | 7.96 | 0.68 | 7.17 | 0.21 | 8.54 | 0.68 |
| 5 + 4 | Attention | I | 4.05 | 0.50 | 4.14 | 0.60 | 4.16 | 1.10 | 4.26 | 0.93 |
| | | II | 4.61 | 1.80 | 4.59 | 1.86 | 4.71 | 2.07 | 4.90 | 1.28 |
| | Cognition | I | 7.25 | 0.79 | 6.97 | 0.67 | 7.09 | 0.73 | 7.23 | 0.70 |
| | | II | 9.10 | 0.95 | 8.47 | 0.73 | 9.45 | 0.55 | 9.04 | 0.43 |
| | Apprehension | I | 7.98 | 0.46 | 8.76 | 0.63 | 7.92 | 0.59 | 8.17 | 0.63 |
| | | II | 9.03 | 0.89 | 8.22 | 0.57 | 8.84 | 0.70 | 9.58 | 0.41 |
| 5 + 4 + 3 | Attention | I | 4.01 | 0.50 | 4.34 | 0.60 | 4.16 | 1.10 | 4.28 | 0.93 |
| | | II | 4.61 | 1.80 | 4.59 | 1.86 | 4.71 | 2.07 | 4.90 | 1.28 |
| | Cognition | I | 7.24 | 0.84 | 7.02 | 0.63 | 7.19 | 0.72 | 7.33 | 0.65 |
| | | II | 8.86 | 0.96 | 8.56 | 0.71 | 8.88 | 0.55 | 9.04 | 0.43 |
| | Apprehension | I | 9.09 | 0.67 | 8.67 | 0.49 | 8.66 | 0.59 | 9.24 | 0.55 |
| | | II | 9.96 | 0.68 | 10.99 | 0.25 | 10.09 | 0.42 | 10.60 | 0.48 |

Table V clearly indicates the relations discovered with regard to the relative magnitude of these threshold averages.

In every case, Red in general gives a high limen and Green a low one. Yellow and Blue have a tendency to be intermediate and variable. This situation is in general true for all 3 systematic categories and for all 3 degrees of subjective assurance for every *O*.

TABLE V

| *O* | Relative positions of limens | | | |
|---|---|---|---|---|
| | Highest | 2nd | 3rd | Lowest |
| SO | R | Y | B | G |
| SC | (R | B) | (G | Y) |
| YN | R | (Y | B) | G |
| MM | R | (B | Y) | G |

For SC and SO, trained *O*s, there is also observable a characteristic difference between the size of the coefficient of precision (h) for Red and Green. The coefficients for Red are almost invariably larger than those for Green; the individual variations, however, not being exceedingly dissimilar. No such relationship can be discovered for the coefficients for Blue and Yellow. For the untrained observers, YN and MM, however, no such relationship in the size of the coefficient of precision is noticeable.

## Discussion

Introspective reports were given by all the *O*s frequently during the experiment. An analysis and consideration of these reports did nothing more than indicate to the *E* that the conditions for the formation of the different judgments remained constant throughout the experiment. There is nothing in the introspective reports which throws any light upon the threshold differences which have been discovered for the different colors. The explanation of these results might depend upon several possible facts.

(1) *Intensity of the colors.* It would seem unlikely that the intensity of the colors would be the correct explanation in the light of the results obtained by Cooper in which he discovered that no constant effect was produced in 3 of his 4 *O*s when he exposed materials of Black, Medium Gray, and Light Gray on a White background.[4] His method and procedure was the same as that indicated in the present study; the only difference being the nature of the materials exposed. If intensity of the present materials were to give the effect indicated, it would be obvious that a still greater effect would have been observable in the uncolored materials which Cooper employed.

(2) *Saturation of the Stimuli.* It will be remembered that in the set of Hering papers, Red and Blue are highly saturated while the Yellow and Green are less highly saturated. Saturation might account for the relationship position of Red giving the highest limen and Green giving the lowest limen, but when one considers the unsaturated nature of the Yellow stimulus and its high position on the liminal scale, it would seem that such an explanation is highly improbable.

(3) *Anklingen times for the different colors.* It will be remembered that Kunkel has discovered that the order of rapidity of the *Anklingen* times gives Red as fastest, Green as slowest, with Blue intermediate.[5] The actual times he gives are, for Red 0.057 sec., Blue 0.091 sec., and Green 0.133 sec. Such a situa-

[4] S. F. Cooper, The effect of brightness in the range of attention experiment, this Journal, 40, 1928, 254-274.

[5] Kunkel, *Arch. f. d. ges. Physiol.*, 9, 1874, 197.

tion would explain very obviously the threshold differences when we consider that we are dealing with materials tachistoscopically exposed for an exposure of approximately 40 sigma. More recently, however, Bills has shown that the order of the *Anklingen* times varies considerably as the result of the methods employed and as a result of the intensity of the stimuli.[6] Bills does find, however, that when one approaches threshold values of stimuli, the order is Red highest, Yellow, Blue, and Green.

We are not prepared to state dogmatically that this is an explanation of our data. It would seem, however, as if the differences in *Anklingen* were a very possible explanation when one considers that the tachistoscopic exposure was shorter than the time necessary for any of these colors to have reached their perceptual maximum.

## Summary

(1) The judgments for the range of Attention, Cognition, and Apprehension fall into curves of the phi-gamma type for red, yellow, blue, and green stimuli.

(2) The limens for Attention are smallest, for Cognition intermediate, and for Apprehension the largest, in confirmation of Oberly's results with uncolored stimuli.

(3) The limens for Red are constantly largest for each of the three systematic categories and for the different degrees of subjective assurance. The limens for Green are similarly smallest, with those for Yellow and Blue intermediate.

(4) No such relation is discovered with regard to the magnitude of the values of the coefficients of precision.

(5) Brightness and saturation differences do not seem to account for these liminal differences, and the *Anklingen* times of the colors possibly offer a more satisfactory explanation.

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[6] M. A. Bills, The lag of visual sensation in its relation to wave lengths and intensity of of light. *Psychol. Mon.*, 28, 1920, no. 127, 1-101.